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Observations on Mold Development and on Deterioration in Stored Yellow Dent Shelled Corn

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SUMMARY

Examinations during 3 consecutive years were made in Iowa for mold development in yellow dent shelled corn stored in steel bins of 1,000-2,740 bushel capacities. The first was made during August and September 1941, the second in March 1942 and the third in April 1943. Different bins were examined in each of the three inspections. Bins reportedly containing some corn of 14 percent or more moisture were examined and probed in the first examination, those with corn of 13.5 percent or more moisture in the second examination; no selection of bins for moisture content was made in the third examination. All of the bins examined had been filled during the fall previous to sampling.

In the first examination, approximately 50 percent of 58 bins showed mold development with accompanying mold-matting of corn in the upper central surface region. In late March 1942, approximately 73 percent of 22 bins showed this same condition, while in early April 1943, approximately 75 percent of 37 bins were affected. The extent of mold development varied, in the different bins, from a small area of several feet in diameter and 6 inches in depth to the entire diameter of the bin and $2\frac{1}{2}$ to 4 feet in depth.

Penicillium palitans was the predominating fungus in the molding corn over the first winter period of storage, with the other fungi, such as *Aspergillus flavus*, *A. candidus*, members of the *A. glaucus* group and the blue-eye fungi *(Penicillium rugulosum* and *P. chrysogenum*, with *P. palitans* included), appearing as distinct stratifications. The blue-eye fungi were the only ones of several tested in the laboratory which developed at 9° and 0.5° C.

The late summer inspection of 1941 revealed stratification of some of these same fungi but in less distinct zones. These zones were heavily intermixed with species of *Mucor*, *Rhizopus*, *Absidia*, *Penicillium*, *Aspergillus* and other less defined organisms. Blue-eye corn occurred on the outer rim of the heavily molded zone; immediately beyond and below this, in the drier corn, *A. candidus* and members of the *A. glaucus* group occurred.

The moisture content of the corn in the bins was generally higher in the upper 2-foot region where mold development was prevalent. Below this the moisture content was at a slightly decreasing lower level throughout.

The deterioration of corn as measured by germinability losses and fat acidity increases was nearly complete in the upper 2 feet of most bins examined but was progressively less toward the lower parts. Such losses were most marked by late summer after the corn had undergone a winter, spring and summer period of

storage. Similar but less marked losses occurred even over a winter period of storage.

Insect infestations were absent in all but a few bins, where they were light to moderate.

Laboratory studies revealed the following minimum relative humidities for spore germination: *Aspergillus candidus* and *A. amstelodami*, 72.5 percent; *A. niger*, 80 percent; *A. flavus*, 82.5 percent; *Penicillium chrysogenum*, 85 percent; and *P. rugulosum*, *P. palitans* and *Mucor racemosus*, 87.5 percent.

The molding of two yellow dent hybrids, infested and noninfested with spores from each of eight fungi, was slightly earlier and more luxuriant over a range of relative humidity (97.5 to 72.5 percent) on a soft, starchy corn than on a hard, flinty-type corn. Infestations with fungus spores hastened the first appearance of mold growth on this corn. A relative humidity of approximately 65 percent was extrapolated as the lower limit for mold growth on corn.

Laboratory storage of 9.7, 11.0, 12.0, 13.0 and 14.0 percent moisture corn for 1 year in tight metal containers at 20-25° C. produced germinability losses of near 50 percent in the 14.0 percent moisture corn with accompanying fat acidity increase and blue-eye development. The 9.7 to 13.0 percent moisture corn at this time showed no germinability losses, with the 12.0 and 13.0 percent moisture corn showing only slight fat acidity increase. After 2 years of storage the 14.0 percent moisture corn sustained complete loss of germinability with increase in fat acidity to 68.9 units from the original 24.9 units and damage increase to 45.6 percent from the original 3.6 percent. In the same period the drier corn showed lower germinability losses and fat acidity increases, with no change in the percentage of damaged corn. Corn of 9.7 percent moisture showed no change in any of these characteristics during this period.

Observations on Mold Development and on Deterioration in Stored Yellow Dent Shelled Corn[1]

By G. Semeniuk, C. M. Nagel and J. C. Gilman[2]

In the Corn Belt of the United States storage of shelled yellow dent corn in steel bins of 1,000-2,740 bushel capacities for periods of several years[3] accented some of the problems of corn deterioration. One problem was the damage resulting from mold development, especially in certain areas and during years when crib-drying of ear corn was inadequate. Molds frequently developed from failure to observe the set moisture limits for shelled corn storage (13.5 percent maximum) and from natural increase in moisture in the upper parts of the bins. Other problems were concerned with deterioration reflected by corn germinability losses and fat acidity increases.

To ascertain the extent of such deterioration and the identity of the molds, bin-stored shelled corn (owned by the Commodity Credit Corporation) was examined in areas of Iowa where high-moisture corn was known to occur. Different sets of bins were investigated at each of three periods: the first during August-September 1941, the second during late March 1942 and the third during early April 1943. The bins were all different and were examined only once except for four bins in the 1942 inspection which were re-examined. In 1941 and 1942 only bins known to contain some high-moisture corn were visited, while in 1943 all available bins were visited without previous knowledge of their corn-moisture content. In all of the bins, the shelled corn had been placed in storage during October, November and December of the year previous to examination. Thus, the interval of storage was over the winter period, except in the 1941 examination, when the interval of storage also included the succeeding spring and summer.

To supplement these bin examinations, certain studies were conducted in the laboratory. These studies comprised an investigation of some factors influencing the molding and deteriora-

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[1]Project No. 754 of the Iowa Agricultural Experiment Station, in cooperation with the Commodity Credit Corporation through the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

[2]The writers wish to express their thanks to E. A. Ellison, grain storage specialist, Agricultural Adjustment Administration; to H. J. Barre, formerly research assistant professor and agent, respectively, of the Iowa Agricultural Engineering Section, Iowa Agricultural Experiment Station and the Bureau of Plant Industry, Soils and Agricultural Engineering; and to I. E. Melhus, Botany and Plant Pathology Section, Iowa Agricultural Experiment Station, for their interest and assistance in the present work.

[3]The ever-normal granary program of the United States Government.

tion of corn. The factors investigated were: (1) the minimum temperature and moisture requirements for the development of specific fungi isolated from molding corn in the bins; (2) the relation of atmospheric humidity to the molding of corn; and (3) the deterioration of low-moisture corn when stored in tight containers.

PART I—BIN EXAMINATIONS

BIN EXAMINATION PROCEDURE

In 1941, bins were selected from the available records[4] which showed the presence of some corn of 14 percent or more moisture at the time of filling or at some subsequent date of inspection. In 1942, selections were made from similar records of bins containing corn having 13.5 percent or more moisture at the time of filling. In 1943 no bin selections were possible, as moisture records were unavailable. In 1943, and for the most part in 1941 and 1942, the examined bins were in the north-central counties of Iowa. However, a few high moisture bins were found in the central counties of Iowa in 1941 and 1942.

To examine the corn, the bins were entered through an opening in the roof. Corn samples were collected at 1-foot intervals down the center of each bin in sufficient amounts for the isolation of molds and for the determination of corn grade, moisture content, germination percentage, fat acidity and bushel weights. A standard 10-celled, 5-foot grain probe was used for the collection of these samples; an 8-foot extension was added to this for the removal of similar samples at the lower depths. Since approximately 12 feet was the usual depth of corn in the 2,740-bushel bins, an unsampled 2-foot interval occurred between the upper and lower parts of these bins. Temperatures in the corn were determined in the upper half of the bins with the aid of six mercury thermometers which were attached at 1-foot intervals in a groove along the length of a 7-foot pole. This pole was pushed down the center of the corn mass at an angle approximately 15° to the vertical. No temperature readings were made in the lower half of the bins.

Corn grade determinations were made by a licensed grain inspector[5] in accordance with the October 1940 official U. S. Department of Agriculture grain grading standards. Moisture was determined with a Tag-Heppenstall moisture meter. Ger-

[4]Thanks are expressed to the county and state Agricultural Adjustment Administration chairmen for permission to consult these records. These records consisted of moisture percentages for the different lots of corn put into each bin during the fall and for the upper region of each bin during the succeeding spring and summer.

[5]Thanks are due D. F. Atkins, formerly agent, Bureau of Plant Industry, Soils and Agricultural Engineering, for making these determinations.

minability[6] was assessed on 200 kernels placed embryo down on wet blotters and held at 30° C. for 5 days. Germinability losses were taken as the difference between the percentage germinability values and 100 percent. Fat acidities were determined by the method of Zeleny and Coleman (15) and recorded on the basis of 100 grams of dry matter. Bushel weights, corrected to a 15 percent moisture basis, were determined in duplicate, using a container of approximately 100 ml. capacity.

RESULTS OF THE 1941 BIN EXAMINATIONS

The first of the series of examinations was made in late August and early September 1941. The corn in the bins was produced in 1938 and 1939, then stored in cribs on farms until the fall of 1940 at which time it was shelled and placed in the bins. Fifty-eight bins were examined at 26 sites in Cerro Gordo, Greene, Hancock, Mitchell, Story, Winnebago and Worth counties. Only 22 of these were sampled throughout the depth of the contained corn.

The moisture content, germinability, fat acidity, bushel weight and temperature data on the 22 bins are presented in table 1; the interrelationships of certain of these are shown in figs. 1, 2 and 3. The complete set of data on fat acidities and bushel weights is not available on all 22 bins because of small samples or loss of certain samples.

The damage to corn from mold development with accompanying heating was evident in 50 percent of the 58 bins examined. Since the bins were selected because they contained more than the normal amount of moisture, this no doubt accounted for the high percentage of damage found. In addition, the above-normal outdoor temperatures which prevailed throughout most of the bin storage period may have contributed to this condition. The molded corn was confined generally to the upper central surface region and extended to a maximum depth of approximately 2 feet in the center across two-thirds the radius of the bin. In one instance it extended entirely across the diameter of the bin to a uniform depth of approximately 4 feet from the surface. This moldy condition frequently could not be readily detected by casual inspection because of a thin top layer of sound corn, a few kernels in depth, which covered the underlying moldy corn. The molded corn frequently was sufficiently matted together with mycelium to support the weight of a man.

The moisture, fat acidity and loss of germinability of the corn within the bins are plotted in fig. 1. The 22 bins were divided into two groups according to the moisture content in the center

[6]Germinability, fat acidity and mold development were used as indicators of the extent of deterioration in the corn. Since this corn was not to be used for planting purposes these indicators have little significance as guides for handling seed corn.

TABLE 1. SUMMARY OF MOISTURE CONTENT, GERMINABILITY, FAT ACIDITY AND WEIGHT PER BUSHEL OF CORN AT 1-FOOT INTERVALS DOWN THE CENTER OF 22 DIFFERENT COMMODITY CREDIT CORPORATION STEEL BINS LOCATED IN CERRO GORDO, GREENE, HANCOCK, WINNEBAGO AND WORTH COUNTIES, IOWA. AUGUST AND SEPTEMBER, 1941.

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
Cerro Gordo..	Clear Lake...	369	Moisture (%).....	14.2	13.8	13.0	12.6	12.6	13.1	13.0	12.5	12.8	13.0	Corn slightly damp, musty in small area on top.
			Germination (%)*.	0.0	1.0	3.0	44.0	80.0	67.0	...†	....	82.0	70.0	
			Wt. per bu........	55.2	55.1	56.6	56.2	57.5	59.1	57.8	57.6	....	56.9	
	Clear Lake...	270	Moisture (%).....	13.3	13.3	13.8	13.0	13.4	13.8	13.0	13.5	12.9	13.1	Corn in good condition.
			Germination (%)..	9.0	19.0	25.0	23.0	30.0	33.0	59.0	58.0	69.0	71.0	
			Wt. per bu........	56.9	55.1	55.5	57.0	....	....	54.6	56.9	56.4	56.3	
			Fat acidity (units).	30.3	34.1	29.8	40.2	42.4	....	36.3	27.8	....	29.2	
	Clear Lake...	373	Moisture (%).....	18.5	15.6	13.8	13.9	13.9	14.1	14.5	14.4	14.4	14.1	Corn damp, hot to 3 ft. depth with mold development 2 ft. below the surface.
			Germination (%)..	0.0	0.0	1.0	1.0	1.0	2.0	6.0	31.0	26.0	63.0	
			Wt. per bu........	48.0	52.6	54.8	56.2	56.4	57.1	56.0	55.7	55.9	....	
			Fat acidity (units).	215.9	148.2	82.0	....	....	....	....	....	....	....	
			Temperature (°C).	42.2	....	43.8	....	....	....	....	....	....	....	
	Plymouth....	431	Moisture (%).....	15.8	14.5	13.4	13.1	13.2	13.5	13.3	13.6	13.1	12.9	Slightly damp on surface, in an area 3 ft. in diameter and 6 in. in depth.
			Germination (%)..	0.0	1.0	0.0	21.0	55.0	77.0	83.0	81.0	80.0	90.0	
			Wt. per bu........	53.5	56.0	57.5	59.1	57.4	58.1	57.6	57.7	56.8	57.5	
			Fat acidity (units).	120.9	133.9	63.8	41.4	34.6	36.1	34.8	36.1	31.1	35.8	
	Portland.....	408	Moisture (%).....	15.3	13.6	13.2	13.6	13.6	13.0	13.0	12.9	13.1	12.0	Corn slightly damp on top central area.
			Germination (%)..	11.0	1.0	1.0	2.0	12.0	62.0	51.0	68.0	83.0	86.0	
			Wt. per bu........	51.9	55.0	54.7	54.2	54.2	....	55.2	....	....	....	
			Fat acidity (units).	67.8	51.2	49.7	42.3	43.5	....	....	....	....	....	
Greene.......	Bayard......	1447	Moisture (%).....	11.5	13.4	11.9	12.1	12.1	11.7	12.2	12.5	11.8	11.4	Corn in good condition. No mustiness detectable.
			Germination (%)..	76.0	90.0	85.0	84.0	....	89.0	82.0	62.0	84.0	90.0	
			Wt. per bu........	57.6	56.7	58.3	58.3	58.2	57.8	58.1	55.6	58.1	59.1	
			Fat acidity (units).	30.0	29.5	24.2	29.6	33.2	25.8	26.0	44.5	38.8	23.5	
	Jefferson.....	1325	Moisture (%).....	16.0	13.8	13.5	13.4	13.3	13.4	13.4	13.2	12.8	12.8	Corn musty, hot, moist in upper 2 ft; ⅔ surface area with mold development.
			Germination (%)..	....	....	....	....	6.0	7.0	....	28.0	45.0	75.0	
			Wt. per bu........	54.2	58.3	58.6	57.8	58.9	....	57.1	57.8	57.7	57.8	
			Fat acidity (units).	187.5	163.2	105.3	115.0	64.0	106.0	34.5	51.1	40.0	....	

*Strong and weak germination taken together.
†Insufficient sample.

Table 1 (continued).

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
	Scranton.....	1025	Moisture (%).....	14.3	13.2	12.5	12.2	11.7	13.4	12.1	11.7	11.7	11.8	Upper 18 inches musty over ½ surface area.
			Germination (%)..	1.0	....	16.0	81.0	81.0	88.0	93.0	88.0	81.0	83.0	
			Wt. per bu........	51.0	54.7	57.8	57.4	57.9	57.4	57.8	57.6	....	....	
			Fat acidity (units).	66.2	33.2	32.8	30.3	25.7	35.9	57.8	57.6	....	....	
	Scranton.....	1214	Moisture (%).....	14.5	13.4	12.4	12.2	11.7	12.1	11.5	10.5	10.7	10.3	Corn in apparently good condition, except small area in center on surface which was damp and musty.
			Germination (%)..	2.0	8.0	58.0	61.0	82.0	86.0	79.0	90.0	90.0	79.0	
			Wt. per bu........	54.4	56.9	59.1	....	58.8	57.1	57.5	58.0	58.2	57.3	
Hancock.....	Crystal Lake .	421	Moisture (%).....	15.8	14.4	13.4	13.6	13.6	....	....	....	....	....	Top 2 ft. had been stirred, corn appeared in good condition.
			Germination (%)..	7.0	1.0	29.0	70.0	51.0	....	....	....	....	....	
			Wt. per bu........	53.2	55.3	55.9	57.2	55.2	....	....	....	....	....	
			Fat acidity (units).	72.0	54.6	30.0	29.3	30.1	....	....	....	....	....	
	Crystal Lake .	422	Moisture (%).....	17.8	13.7	13.4	13.4	13.8	13.8	13.4	13.0	13.2	12.7	Upper 2 ft. layer over ⅔ surface area showed extensive mold development. Hot to 4 ft. depth.
			Germination (%)..	....	....	....	....	3.0	56.0	78.0	84.0	64.0	74.0	
			Wt. per bu........	49.0	53.7	55.1	54.7	54.8	56.5	56.5	57.6	56.8	58.1	
			Fat acidity (units).	236.8	158.8	149.4	118.1	90.5	39.2	38.4	36.4	44.3	40.2	
			Temperature (°C).	38.3	....	....	32.8	....	....	....	....	....	....	
	Crystal Lake .	439	Moisture (%).....	15.9	14.0	13.7	13.6	12.4	14.0	14.2	14.3	14.6	14.3	Mold development in upper 2½ ft. Corn warm on surface.
			Germination (%)..	2.0	2.0	....	31.0	60.0	81.0	84.0	80.0	69.0	71.0	
			Wt. per bu........	52.3	53.4	55.1	56.6	56.4	56.1	56.5	58.2	55.9	55.9	
			Fat acidity (units).	158.8	110.9	79.1	34.7	33.5	25.2	21.7	26.2	24.7	25.8	
			Temperature (°C).	30.6	....	....	25.6	....	....	....	....	....	....	
	Crystal Lake .	652	Moisture (%).....	16.8	14.0	13.0	13.2	13.4	....	....	....	....	....	Damp, musty area with blue mold over ¾ of surface extending 2 ft. in depth. White mold on outer edges.
			Germination (%)..	....	....	....	8.0	31.0	....	....	....	....	....	
			Wt. per bu........	51.7	55.9	56.8	58.0	52.4	....	....	....	....	....	
			Fat acidity (units).	134.0	60.8	52.0	38.2	31.9	....	....	....	....	....	
	Crystal Lake .	654	Moisture (%).....	18.9	14.0	14.6	13.6	14.0	14.0	14.2	14.6	14.6	14.3	Mold development over entire surface 2½ ft. in depth. Hot. Bin ¾ filled. Corn shipped as musty, No. 4 yellow.
			Germination (%)..	....	....	....	....	....	4.0	19.0	58.0	49.0	51.0	
			Wt. per bu........	46.8	53.9	55.1	56.5	57.2	....	54.6	55.1	55.2	....	
			Fat acidity (units).	273.0	155.0	144.0	75.2	53.9	70.5	49.2	42.1	45.8	....	
			Temperature (°C).	38.9	35.0	....	33.3	....	30.6	....	....	....	....	
	Duncan......	318	Moisture (%).....	15.2	13.7	13.7	13.2	13.8	12.9	12.7	12.1	11.8	11.9	Damp, warm and molding in upper 2 feet.
			Germination (%)..	....	4.0	23.0	31.0	58.0	86.0	85.0	85.0	74.0	91.0	
			Wt. per bu........	54.3	54.3	56.1	56.7	56.4	56.7	56.9	57.5	57.1	57.8	
			Fat acidity (units).	68.0	58.4	44.6	42.2	41.5	35.0	30.2	31.3	38.0	26.8	
			Temperature (°C).	32.8	....	....	26.7	....	23.9	....	....	....	....	

Table 1 (continued).

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
	Garner.......	394	Moisture (%).....	19.1	15.4	15.2	15.2	15.3	13.6	14.1	14.5	14.4	14.0	Corn hot to 4 ft. depth, moisture condensed on roof, corn germinated at edge of bin. Molds developing.
			Germination (%)..	....	....	....	....	....	3.0	12.0	22.0	28.0	18.0	
			Wt. per bu........	45.6	51.6	53.6	53.2	53.2	54.6	....	56.0	55.9	55.9	
	Hayfield	337	Moisture (%).....	17.8	14.4	13.4	13.4	13.3	....	....	....	....	....	No mold development. High moisture in upper 2 ft. over 1/3 surface area.
			Germination (%)..	....	....	15.0	39.0	48.0	....	....	....	....	....	
			Wt. per bu........	51.9	53.6	54.9	55.2	53.7	....	....	....	....	....	
			Fat acidity (units).	131.7	74.2	39.0	28.9	30.2	....	....	....	....	....	
Winnebago...	Buffalo Center	333	Moisture (%).....	14.1	13.2	12.7	12.4	13.2	....	....	....	....	....	Corn appeared in fairly good condition with some local molded corn along outside edges.
			Germination (%)..	0.0	0.0	19.0	48.0	69.0	....	....	....	....	....	
			Wt. per bu........	56.5	55.0	56.2	57.7	58.1	....	....	....	....	....	
			Fat acidity (units).	103.2	90.9	45.6	30.4	39.5	....	....	....	....	....	
Worth.......	Joice.........	143	Moisture (%).....	16.3	13.2	12.7	13.0	13.4	....	....	....	....	....	Damp area 8 ft. in diameter, warm at 2 ft. depth level.
			Germination (%)..	2.0	0.0	0.0	5.0	14.0	....	....	....	....	....	
			Wt. per bu........	51.4	55.8	56.0	56.7	55.9	....	....	....	....	....	
			Fat acidity (units).	141.7	61.0	48.1	35.7	47.5	....	....	....	....	....	
	Joice.........	145	Moisture (%).....	15.9	13.2	13.0	13.2	13.4	....	....	....	....	....	Blue-eye corn developed in upper 1 ft. layer.
			Germination (%)..	16.0	11.0	23.0	27.0	47.0	....	....	....	....	....	
			Wt. per bu........	54.3	56.6	57.5	59.9	57.9	....	....	....	....	....	
			Fat acidity (units).	75.4	44.0	32.4	28.8	30.7	....	....	....	....	....	
	Hanlontown..	13	Moisture (%).....	19.1	12.5	12.4	12.5	12.3	....	....	....	....	....	
			Germination (%)..	0.0	0.0	0.0	0.0	8.0	....	....	....	....	....	
			Wt. per bu........	45.3	55.9	55.6	55.1	....	....	....	....	....	....	
			Fat acidity (units).	309.5	89.1	53.1	51.6	....	....	....	....	....	....	
	Northwood...	85	Moisture (%).....	17.4	13.0	12.7	13.0	13.2	....	....	....	....	....	Damp in central area 8 ft. in diameter, and 1½ ft. in depth. Blue-eye corn developed.
			Germination (%)..	0.0	0.0	2.0	19.0	57.0	....	....	....	....	....	
			Wt. per bu........	51.9	56.6	56.4	55.9	58.7	....	....	....	....	....	

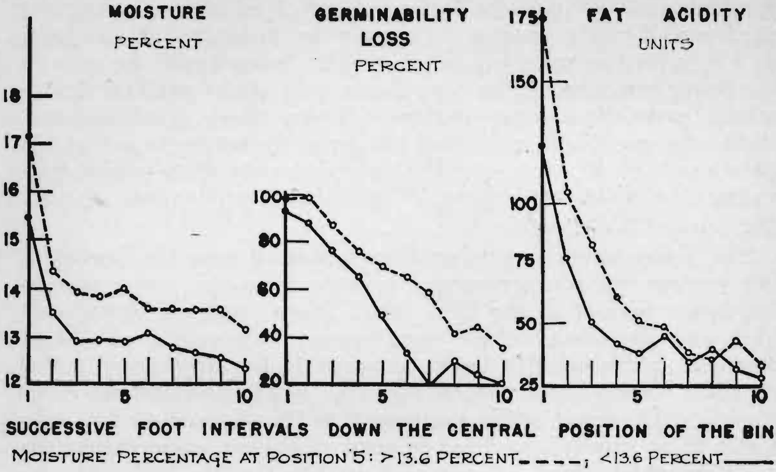

Fig. 1. Moisture content, germinability loss and fat acidity of corn at different positions within two groups of bins having high and low moisture. The high-moisture bins were those containing corn with 13.6 percent or more moisture at position 5; the low-moisture bins were those containing corn with less than 13.6 percent moisture at position 5. August-September 1941.

of the bin. Those containing 13.5 percent moisture or less in bin position 5 constituted one group, and those containing more than 13.5 percent moisture at this same position constituted a second group. The mean values for moisture, fat acidity and loss of germinability for each of the two groups of bins at each of the 10 positions within the bin, numbered from the top to the bottom, are presented.

As may be seen from fig. 1, the moisture content of the corn for the two groups of bins graded sharply upward at bin positions 2 and 1. Below this region the moisture content assumed a fairly constant low level with but slightly lower values at the greater depths. Uniformly higher moistures prevailed at the different bin positions in the higher moisture group of bins.

While these moisture values represent the findings of the August-September 1941 period, they do not necessarily represent the moisture values during the immediate summer, spring and winter period preceding this examination. Corn moistures within the bins are not necessarily constant values, but fluctuate with atmospheric temperature and humidity conditions throughout the year[7]. Corn in bin positions 1 and 2, position 1 more so than position 2, is most subject to losses of moisture during the

[7]Personal communication of unpublished data by W. V. Hukill, Bureau of Plant Industry, Soils and Agricultural Engineering, U.S.D.A., and resident collaborator, Iowa Agricultural Experiment Station.

summer and fall periods and to gains of moisture during the winter and early spring. Changes in moisture of as much as 1.0 percent or more can be expected. In contrast, the corn in the lower positions in the bins shows only slight gradual fluctuations over these same periods. From these considerations, therefore, one might infer that the moisture values found at bin positions 3 to 10, inclusive, are approximately those which prevailed during the preceding 10-12 months, while those at positions 1 and 2 are not.

The losses in corn germinability sustained over the period of bin storage were progressively greater from the lower toward the upper regions of the bins. Such losses occurred in both the high and the low-moisture corn groups. Complete, or nearly complete, germinability losses occurred in the uppermost 2 feet of corn where higher moistures and mold development were present. The losses at bin positions 3 to 10, where there was only slight to no upward gradient in corn moistures, suggest that the position which the corn occupied within the bin had some influence on these losses. In the lower moisture group of bins, greater losses occurred at bin positions 3, 4 and 5 than at any of the lower levels, even though the moisture and fat acidity of the corn at these positions were approximately the same as those lower down. In the high-moisture group of bins, the germinability losses and fat acidity increases were progressively lower toward the bottom of the bins from positions 3 to 10.

Fat acidity showed trends to higher values from the lower toward the upper regions within the bins in much the same way as moisture and germinability losses. The fat acidities were approximately the same for the low and the high-moisture corn groups in the lower half of the bins, but were divergent in the upper half. In the low-moisture corn group the fat acidity values paralleled those of moisture, being higher as the moisture content was greater toward the upper regions. In the high-moisture group of bins the values graded upward more abruptly than did the moisture content of the corn, presumably because the moisture content was sufficiently high to support rapid fat acidity changes.

Very high fat acidities developed in the upper surface foot where the molds grew on the corn. A direct relationship was evident in this region among the test weight per bushel, moisture content and the fat acidity of the corn (fig. 2). A laboratory study of this interrelationship, using pure cultures of different molds, has been reported (8).

The interrelationship between the moisture content and the germinability losses of the corn at the different locations within the bins are presented in another way, as shown in fig. 3. The germinability losses for all the bins were grouped according to

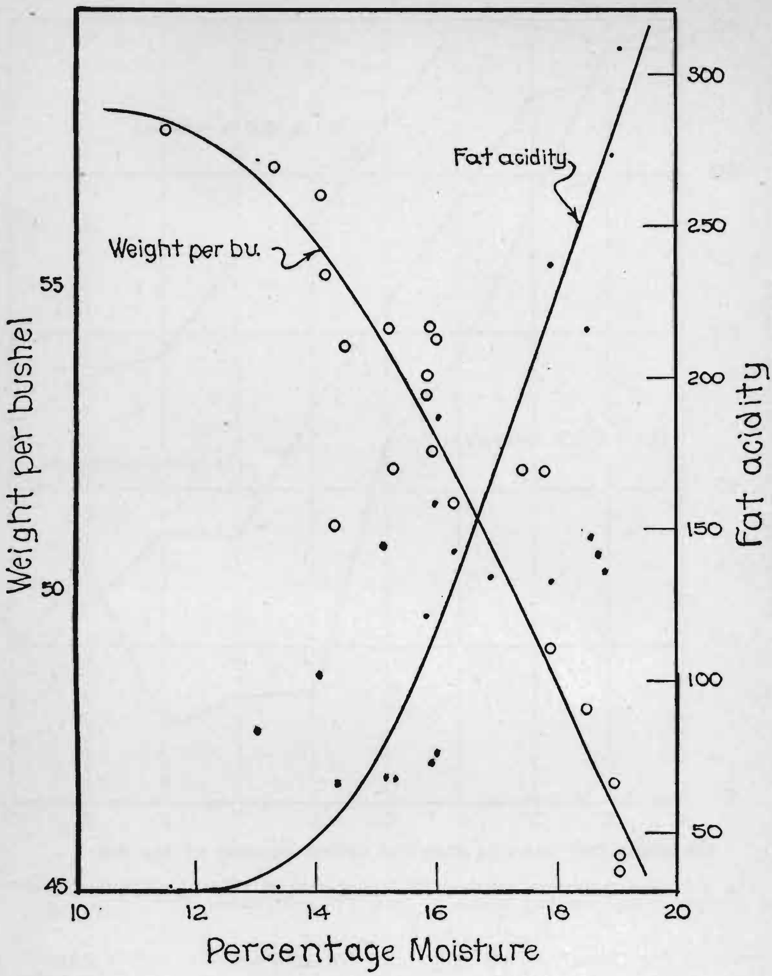

Fig. 2. Relation between fat acidity, weight per bushel and percentage moisture of corn in the upper foot region of bins, August and September 1941.

the position the corn held within the bins and its moisture content at that position. As may be seen from the figure, corn with 14.1-15.0 percent moistures suffered germinability losses of from 50 percent at the bottom of the bins to near 100 percent in the upper 4 feet. Corn with 13.1-14.0 percent moistures sustained correspondingly lower losses at these same bin positions. The germinability losses varied from approximately 30 percent in the lower 4 feet to nearly 100 percent in the upper 3 feet.

Corn with 12.1-13.0 percent moistures showed germinability

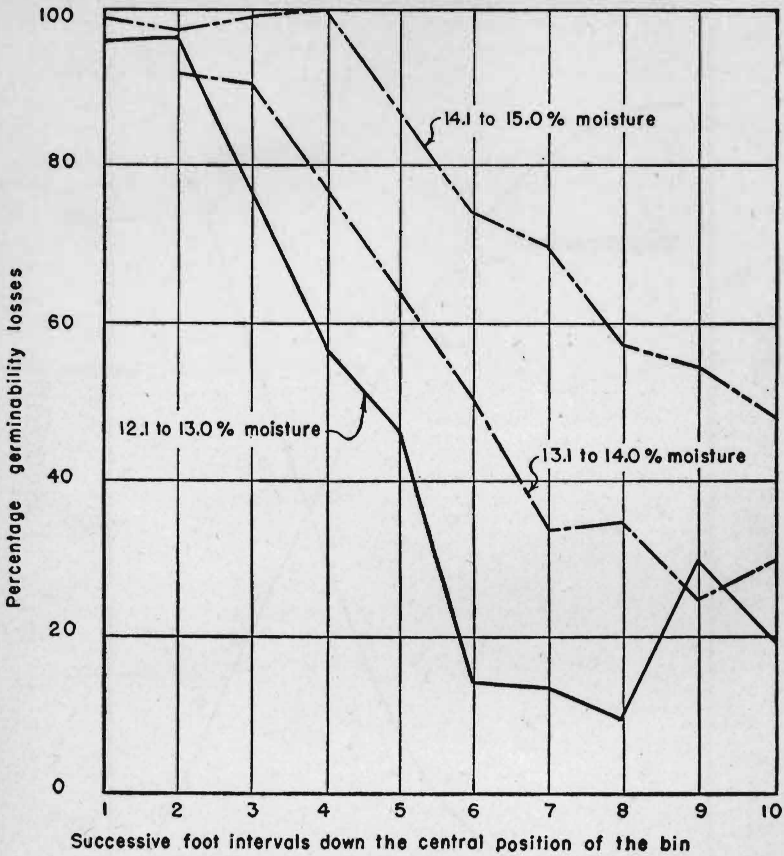

Fig. 3. Mean percentage germinability loss of corn of different moisture contents at different central positions within 22 bins, August-September 1941.

losses in the upper 5 feet only. In this region, the losses graded abruptly from nearly 15 percent at position 6 to nearly 100 percent at position 2. A few corn samples of 12.0 percent and lower moisture content, which were found at different positions within the bins and not represented in fig. 3, showed high germinability whether located at the upper surface or at some lower depth.

While a portion of the germinability losses occurred during crib storage of ear corn, the greatest portion occurred during bin storage of the shelled corn. The nearly complete loss of germinability in the upper 2 feet of corn was doubtless associated with the high moistures prevalent there. The progressively lower losses sustained at the lower depths are not so clearly related to the progressively lower corn moistures present at these depths, since the moisture varied a small fraction of 1 percent at most. The direct participation of micro-organisms in causing these losses appeared improbable except in the upper surface 2 feet of moist corn since the losses in germinability at the lower depths were entirely out of the region of visible micro-organism activity. Germinability tests of the corn from the lower bin levels were not accompanied by extensive mold growth on the germinating kernels as was always the case with corn taken from the immediate vicinity of the molded areas.

RESULTS OF THE 1942 BIN EXAMINATIONS

A second selection of bins for examination was made in late March 1942 in Cerro Gordo, Hancock and Hamilton counties. The purpose of this early examination was to determine whether or not mold growth and deterioration would occur over a single winter period. Only bins containing some corn with 13.5 percent or more moisture at the time of filling were selected. These bins had been filled in the fall of 1941 with corn produced in 1939 and 1940. The 1941-42 winter had been mild with above-normal temperatures.

Of the 22 bins examined, 16, or approximately 73 percent, showed a molded, heated top layer extending across two-thirds of the bin diameter and approximately 6 inches deep. Tests of the samples from 21 bins revealed lower but similar losses in ger-

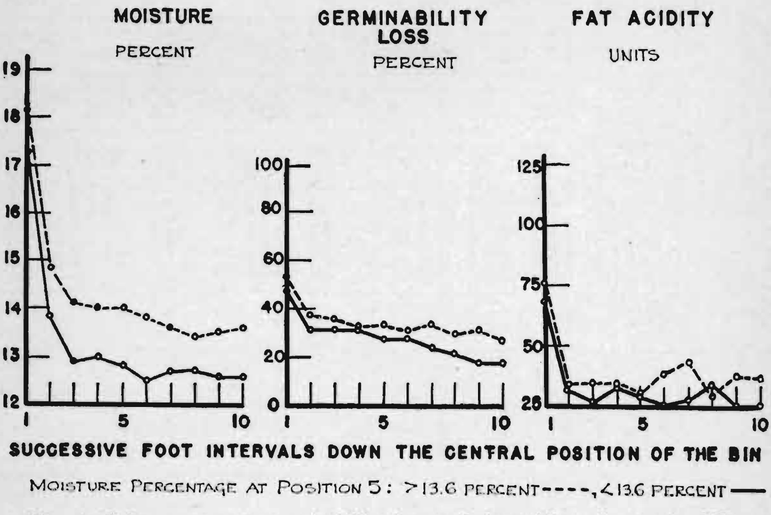

Fig. 4. Moisture content, germinability loss and fat acidity of corn at different positions within two groups of bins having high and low moisture. The high-moisture bins were those containing corn with 13.6 percent or more moisture at position 5, and the low-moisture bins were those containing corn with less than 13.6 percent moisture at position 5. March 1942.

TABLE 2. SUMMARY OF ANALYSES MADE ON CORN IN COMMODITY CREDIT CORPORATION STEEL BINS IN CERRO GORDO, HAMILTON, HANCOCK AND WRIGHT COUNTIES, IOWA. MARCH 25-26, 1942.

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
Cerro Gordo..	Clear Lake...	374	Moisture (%).....	16.3	16.0	15.2	14.9	14.8	15.2	14.3	14.0	13.3	13.8	No visible mold development, corn damp in upper 2-foot layer.
			Germination (%) .	27.5	42.5	54.0	54.5	53.0	52.5	57.5	62.5	68.5	72.5	
			Temperature (°C).	14.2	....	33.0	....	5.0	....	5.0	....	....	....	
	Rockwell.....	355	Moisture (%).....	16.8	14.5	13.5	13.5	13.3	13.8	13.5	13.3	13.3	13.0	Some mold development, corn damp in upper 1-foot layer.
			Germination (%)..	21.0	39.0	44.5	43.0	43.5	47.0	63.0	63.5	59.0	76.0	
			Temperature (°C).	10.5	....	3.0	....	3.0	....	3.0	....	....	....	
	Rockwell.....	356	Moisture (%).....	21.2	15.2	13.8	14.7	13.2	12.8	13.0	13.3	13.5	13.5	Mold development in area 8 feet in diameter, 1 foot deep.
			Germination (%)..	12.0	13.5	14.0	23.5	26.5	24.5	32.0	35.0	47.5	52.0	
			Temperature (°C).	15.5	....	3.0	....	2.5	....	2.0	....	....	....	
Hamilton.....	Blairsburg....	526	Moisture (%).....	19.5	15.2	14.2	14.3	14.0	14.3	14.3	13.6	13.4	13.4	Development of blue mold. Corn damp and "caked" in upper 2-foot layer.
			Germination (%)..	51.0	69.0	77.5	86.0	58.5	71.5	69.0	64.0	63.0	60.0	
			Wt. per bu. (lbs.)..	....	55.5	....	....	....	54.5	56.0	56.5	....	....	
			Total damage (%)	8.3	6.2	2.4	2.2	3.0	3.0	2.8	2.8	2.5	2.6	
			Blue eye (%).....	2.0	0	0	0	0	0	0	0	0	0	
			Grade...........	SY	3Y	2Y	2Y	1Y	2Y	2Y	1Y	1Y	1Y	
			Odor*...........	M	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	58.9	40.3	40.2	36.3	35.5	28.7	39.1	33.8	37.1	33.7	
			Temperature (°C).	12.0	....	7.0	....	5.5	....	5.0	....	....	....	
	Blairsburg....	530	Moisture (%).....	16.0	13.4	12.5	12.7	12.8	13.0	13.3	13.4	13.3	13.3	Slight mold development. Corn damp in upper 1-foot layer.
			Germination (%)..	83.5	89.5	90.0	84.0	85.5	94.5	88.5	81.5	83.5	91.5	
			Wt. per bu. (lbs.) .	No	No	57.5	58.0	No	57.5	No	57.0	58.0	58.0	
			Total damage (%).	1.7	2.3	1.8	2.2	2.0	2.4	2.6	2.2	3.0	3.0	
			Blue eye (%).....	0	0	0	0	0	0	0	0	0	0	
			Grade...........	3Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	
			Odor............	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	41.8	31.8	28.7	40.2	30.6	30.7	27.7	25.6	41.8	22.2	
			Temperature (°C).	11.0	....	6.0	....	6.0	....	5.5	....	....	....	
	Blairsburg....	534	Moisture (%).....	17.5	14.5	13.8	14.0	14.3	14.0	13.8	13.4	13.8	13.5	Development of blue mold. Corn damp and caked in upper 1-foot layer.
			Germination (%)..	76.0	87.5	74.5	85.0	78.0	44.5	52.5	57.0	68.0	64.0	
			Wt. per bu. (lbs.) .	53.5	....	55.5	....	....	....	55.5	....	56.5	....	
			Total damage (%).	3.5	2.4	2.0	2.1	1.7	2.3	1.8	1.5	1.8	1.6	
			Grade...........	3Y	2Y	1Y	1Y	2Y	1Y	1Y	1Y	1Y	1Y	
			Odor............	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	38.7	31.8	27.1	23.6	22.2	46.2	37.6	28.8	32.2	40.7	
			Temperature (°C).	13.0	....	5.0	....	5.0	....	4.5	....	....	....	

*M=musty. N=normal.

Table 2 (continued).

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
	Blairsburg....	535	Moisture (%).....	18.1	14.8	13.8	13.6	13.8	14.2	13.9	12.9	13.6	14.2	Mold development in upper 10-inch layer. Corn very damp and starting to "cake," involving ⅔ of area.
			Germination (%)..	53.5	79.5	74.0	80.5	78.0	64.5	77.0	84.5	82.5	71.5	
			Wt. per bu. (lbs.) .	50.0	54.0	55.5	55.0	....	54.0	55.0	55.0	54.5	....	
			Total damage (%).	8.8	4.5	2.7	2.5	2.6	3.5	4.7	3.0	2.8	3.0	
			Blue eye (%).....	4.0	2.0	....	....	0.3	....	0.3	....	....	....	
			Grade...........	3Y	2Y	1Y	1Y	1Y	2Y	2Y	1Y	1Y	2Y	
			Odor............	M	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	95.9	36.4	43.9	39.3	39.7	48.0	57.9	58.8	34.9	47.4	
			Temperature (°C).	11.0	....	6.0	....	5.5	....	4.5	....	....	....	
	Blairsburg....	536	Moisture (%).....	14.6	13.8	13.6	14.0	14.0	13.9	13.9	13.8	13.3	13.4	Some mold development. Corn damp.
			Germination (%)..	85.5	78.5	76.5	66.5	71.5	71.5	66.0	64.5	63.0	75.0	
			Wt. per bu. (lbs.) .	....	755.5	....	56.0	....	56.0	....	57.0	....	....	
			Total damage (%).	1.8	1.5	2.0	3.0	3.5	3.8	3.5	3.6	3.5	4.0	
			Blue eye (%).....	....	....	....	....	0.6	....	....	....	....	....	
			Grade...........	2Y	1Y	2Y	1Y	2Y	2Y	2Y	2Y	2Y	2Y	
			Odor............	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	39.8	26.0	31.3	56.1	89.5	52.2	80.8	36.0	49.1	45.4	
			Temperature (°C).	13.5	....	5.0	....	5.0	....	4.0	....	....	....	
	Kamrar......	1142	Moisture (%).....	17.6	13.6	13.1	13.1	13.6	14.0	14.1	14.1	13.8	13.8	Development of blue mold. Corn damp in upper 1-foot layer.
			Germination (%)..	72.0	89.5	....	81.0	77.5	83.5	80.5	83.5	84.5	81.5	
			Wt. per bu. (lbs.) .	52.0	57.0	57.0	57.0	56.0	56.0	56.0	56.0	56.0	....	
			Total damage (%).	42.6	3.4	2.3	2.8	4.4	2.7	3.3	3.5	3.3	3.0	
			Blue eye (%).....	40.0	2.6	0.2	0	2.6	0	0	0	0	0	
			Grade...........	SY	2Y	1Y	1Y	2Y	1Y	2Y	2Y	2Y	1Y	
			Odor............	M	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	91.3	35.3	36.2	40.1	37.8	29.1	34.8	31.6	26.6	32.2	
			Temperature (°C).	13.0	....	6.0	....	4.5	....	3.5	....	....	....	
	Kamrar......	1143	Moisture (%).....	16.9	14.5	13.8	13.9	13.9	14.0	....	....	....	....	Development of blue mold. Corn damp and "caked" in upper 6-inch layer. Bin ½ filled.
			Germination (%)..	55.0	79.0	80.5	83.0	84.5	....	....	....	....	....	
			Wt. per bu. (lbs.) .	54.0	56.0	57.0	57.0	....	....	....	....	....	....	
			Total damage (%).	11.6	3.0	3.4	3.0	2.7	....	....	....	....	....	
			Blue eye (%).....	9.0	....	1.6	....	....	....	....	....	....	....	
			Grade...........	SY	2Y	2Y	1Y	1Y	....	....	....	....	....	
			Odor............	M	N	N	N	N	....	....	....	....	....	
			Fat acidity (units).	86.5	30.5	39.2	29.7	40.7	....	....	....	....	....	
			Temperature (°C)	16.0	....	11.0	....	9.0	....	....	....	....	....	

Table 2 (continued).

Location		Bin no.	Determinations	Position within bin in successive foot intervals from the top										Observations on corn within bin
County	Town			1	2	3	4	5	6	7	8	9	10	
	Stanhope.....	914	Moisture (%).....	17.5	15.7	14.3	14.0	13.9	13.2	13.3	13.3	13.3	13.4	Development of blue mold. Corn damp and "caked" in upper 6-inch layer.
			Germination (%)..	64.0	70.0	54.5	55.5	61.0	74.5	61.5	60.5	72.0	71.5	
			Wt. per bu. (lbs.).	54.5	56.5	56.5	56.0	55.5	56.5	....	57.0	57.5	57.5	
			Total damage (%).	5.6	2.8	2.3	2.0	2.2	2.1	1.8	2.0	2.4	3.0	
			Blue eye (%).....	3.3	1.7	....	....	....	....	....	....	....	....	
			Grade...........	3Y	3Y	2Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	
			Odor...........	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	75.1	35.2	35.6	30.8	28.9	23.1	25.8	25.8	21.4	26.8	
			Temperature (°C).	16.0	....	8.0	....	5.0	....	4.0	....	....	....	
	Stanhope.....	916	Moisture (%).....	16.5	14.2	12.8	13.0	13.1	....	....	....	....	....	Development of blue mold. Corn damp in upper 6-inch layer. Bin ⅔ filled.
			Germination (%)..	55.0	72.0	75.0	70.0	73.0	....	....	....	....	....	
			Wt. per bu. (lbs.).	53.0	55.5	55.5	56.5	56.5	....	....	....	....	....	
			Total damage (%).	6.8	2.6	2.0	1.7	1.9	....	....	....	....	....	
			Blue eye (%).....	4.5	0.2	....	....	....	....	....	....	....	....	
			Grade...........	SY	2Y	1Y	1Y	1Y	....	....	....	....	....	
			Odor...........	M	N	N	N	N	....	....	....	....	....	
			Fat acidity (units).	59.0	41.8	31.9	27.6	28.1	....	....	....	....	....	
			Temperature (°C).	13.0	....	13.0	....	9.0	....	....	....	....	....	
	Stanhope.....	933	Moisture (%).....	17.0	12.7	12.0	11.9	11.5	10.7	10.4	10.6	10.4	10.3	No visible mold development, but top layer of corn had been removed.
			Germination (%)..	67.0	84.5	84.0	89.0	97.0	97.0	95.5	95.0	97.0	95.0	
			Wt. per bu. (lbs.).	53.5	56.5	56.5	56.5	57.0	57.5	57.5	57.5	58.0	....	
			Total damage (%).	2.6	2.0	1.7	2.1	1.8	1.5	2.4	1.8	1.6	1.6	
			Grade...........	3Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	
			Odor...........	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	33.2	23.2	31.6	31.0	29.6	29.9	24.4	28.1	28.7	24.4	
			Temperature (°C).	18.0	....	10.0	....	8.0	....	7.0	....	....	....	
	Stanhope.....	934	Moisture (%).....	17.6	13.1	11.9	11.4	11.5	10.9	10.3	11.3	11.3	11.3	No mold development but top layer had been removed.
			Germination (%)..	74.0	96.5	97.5	96.5	94.5	96.5	94.0	95.0	92.0	92.5	
			Wt. per bu. (lbs.).	52.5	57.0	57.0	56.0	....	57.5	57.0	57.5	57.0	56.0	
			Total damage (%).	2.0	1.8	1.6	1.8	2.2	1.7	1.8	2.0	1.7	2.0	
			Grade...........	4Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	
			Odor...........	N	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	30.4	27.4	26.6	31.4	30.2	24.5	24.3	13.4	20.8	18.4	
			Temperature (°C).	20.0	....	11.5	....	10.0	....	8.0	....	....	....	
Hancock.....	Britt.........	343	Moisture (%).....	17.0	14.4	14.0	13.8	13.9	....	....	....	....	....	Abundant blue mold development. Corn damp and heating in upper 10-inch layer over ⅔ of surface area.
			Germination (%)..	54.5	70.5	79.0	88.5	80.0	....	....	....	....	....	
			Temperature (°C).	8.0	....	5.0	....	4.0	....	2.5	....	....	....	

Table 2 (continued).

Location		Bin	Determinations	Position within bin in successive foot intervals from the top										Observations on corn
County	Town	no.		1	2	3	4	5	6	7	8	9	10	within bin
	Garner.......	442	Moisture (%).....	23.0	15.4	14.4	14.0	13.9	13.9	13.8	13.6	13.9	13.5	
			Germination (%)..	7.0	24.0	25.5	32.0	24.5	59.0	56.5	62.5	51.5	49.0	
			Temperature (°C).	12.5	....	25.0	....	4.5	....	3.0	....	2.5	....	
	Garner.......	443	Moisture (%).....	19.7	15.7	15.2	14.6	14.4	13.5	13.4	13.1	13.1	14.4	Development of blue mold. Corn damp and "caked" in upper 8-inch layer on ⅔ of surface.
			Germination (%)..	21.5	40.5	28.0	37.5	43.5	30.0	29.5	39.0	37.5	47.0	
			Temperature (°C).	27.0	....	5.0	....	4.0	....	2.0	....	....	....	
	Goodell......	58	Moisture (%).....	16.6	14.0	13.3	13.5	13.4	13.3	13.5	13.5	13.8	13.5	No mold development, surface layer of corn previously removed. Corn damp in upper 6-inch layer.
			Germination (%)..	47.0	54.5	53.0	58.5	60.5	58.5	58.0	68.5	77.5	74.0	
			Temperature (°C).	3.5	....	8.0	....	5.0	....	2.0	....	....	....	
	Goodell......	448	Moisture (%).....	18.8	14.6	14.4	14.4	14.0	....	....	....	....	....	Mold development. Corn damp and rotting in upper 6-inch layer.
			Germination (%)..	44.0	73.0	69.5	79.0	59.0	....	....	....	....	....	
			Temperature (°C).	4.0	....	6.0	....	5.0	....	....	....	....	....	
Wright.......	Woolstock....	3111	Moisture (%).....	18.4	14.2	13.1	13.1	13.8	12.3	12.6	12.4	12.4	12.4	Development of blue mold. Corn damp and "caked" in upper 8-inch layer.
			Germination (%)..	4.7	85.5	94.0	89.5	88.0	88.5	89.0	86.5	86.5	89.5	
			Wt. per bu. (lbs.) .	....	55.5	57.0	57.0	....	....	....	55.5	55.5	....	
			Total damage (%).	85.0	3.4	3.3	2.7	2.5	1.8	2.0	2.2	1.7	1.8	
			Blue eye (%).....	75.0	....	....	....	....	....	....	....	....	....	
			Grade............	SY	2Y	2Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	
			Odor.............	M	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	127.3	40.6	25.5	22.8	25.2	23.7	26.9	24.4	24.8	29.3	
			Temperature (°C).	11.0	....	6.0	....	5.0	....	3.0	....	....	....	
	Woolstock....	3112	Moisture (%).....	16.8	13.1	13.4	13.6	13.4	13.0	13.4	13.4	13.6	13.4	Development of blue mold. Corn damp and "caked" in upper 6-inch layer.
			Germination (%)..	66.5	95.0	86.5	80.5	86.5	83.0	84.5	86.0	87.5	86.5	
			Wt. per bu. (lbs.) .	50.0	55.5	56.0	56.5	....	....	56.5	56.5	55.5	....	
			Total damage (%).	70.0	2.6	2.8	2.3	2.5	1.7	3.0	2.8	3.6	3.0	
			Blue eye (%).....	66.0	0	0	0	0	0	0	0	0	0	
			Grade............	SY	1Y	1Y	1Y	1Y	1Y	1Y	1Y	1Y	2Y	
			Odor.............	M	N	N	N	N	N	N	N	N	N	
			Fat acidity (units).	170.2	36.1	20.1	33.2	30.3	22.1	36.9	36.2	47.5	37.4	
			Temperature (°C).	11.5	....	4.0	....	3.5	....	2.0	....	....	....	

minability and increases in fat acidity compared to those found in 1941 (table 2 and fig. 4). Since the corn had been in bin storage only over the winter period, these lower losses are understandable. Closer agreement existed at this early examination between gradations in moisture, germinability losses and fat acidity changes at the different bin positions than existed in the August-September 1941 examination. When the germinability losses at the different positions were grouped according to the corn moisture content at these positions, as was done for fig. 3 of the preceding examination, fairly straight, horizontal lines were obtained. These lines held the same relative position to one another according to their moisture groupings as those in fig. 3.

High fat acidities and lower bushel weights were recorded in the upper molded regions.

On re-inspection of four bins 4 months later, a further slight lowering of the germinability was detected in the upper regions of three bins.

RESULTS OF THE 1943 BIN EXAMINATIONS

The 1942-43 winter in Iowa was generally cold, with below-normal temperatures most of the time. A third set of new bins was examined during the first week in April 1943 to determine whether or not mold growth and deterioration would occur under these colder conditions. In Hancock and Winnebago counties all available bins which had been filled during the fall of 1942 with corn produced in 1941 were examined. No selection of bins for the higher moisture corn was made in this examination, as such records were not available. Corn samples were removed for examination from the upper half of 12 bins.

Of the 37 bins visited, 28, or approximately 75 percent, showed heated, mold-damaged corn in the upper layers as observed in the 1942 examination. Moisture was distributed in the 12 sampled bins in the same manner as in the previous examination, with a maximum of 26.2 percent moisture occurring in the upper first-foot zone in one bin (table 3). Losses in germinability appeared irregular, perhaps because of an initially low germination value of the corn when placed in the bins. This corn had been in crib storage during the warm winter of 1941-42 and the warm, humid early spring of 1942. These conditions doubtless contributed to some deterioration of the corn while in crib storage.

FUNGI WHICH DEVELOPED IN THE STORED CORN

A number of different fungi, some of which were of minor importance, were isolated from the molded corn in the bins. The most important and prevalent fungi isolated over the 3 years were: *Penicillium palitans, P. chrysogenum, P. rugulosum,*

TABLE 3. SUMMARY OF MOISTURE CONTENT, GERMINABILITY AND TEMPERATURE OF CORN IN COMMODITY CREDIT CORPORATION STEEL BINS OF 2,740 BUSHEL CAPACITY LOCATED IN HANCOCK AND WINNEBAGO COUNTIES, IOWA. APRIL 6-7, 1943.

Location		Bin no.	Determinations	Position within bin in successive foot intervals					Observations on corn within bins
County	Town			1	2	3	4	5	
Hancock ..	Britt........	297	Moisture (%)....	22.0	14.9	13.8	13.1	12.9	Top crust of moldy corn 1-ft. depth by 4-ft. radius.
			Germination (%).	1.0	6.0	27.0	28.0	23.0	
			Temperature (°C)	27.5	11.0	....	7.0	6.0	
	Goodell.....	351	Moisture (%)....	18.0	14.5	14.1	14.5	14.4	Top corn damp with mold development beginning.
			Germination (%).	44.0	20.0	26.0	32.0	30.0	
			Temperature (°C)	11.0	6.0	....	4.0	3.0	
	Goodell.....	354	Moisture (%)....	26.2	16.0	14.7	14.1	14.0	Top crust of moldy corn 1 ft. in depth.
			Germination (%).	30.0	39.0	37.0	23.0	31.0	
			Temperature (°C)	20.0	6.0	....	5.0	4.0	
	Goodell.....	448	Moisture (%)....	18.9	....	....	....	....	Top corn damp with some mold development.
			Germination (%).	6.0	....	....	....	....	
	Klemme.....	243	Moisture (%)....	17.9	14.5	13.6	13.5	13.4	As above.
			Germination (%).	7.0	3.0	10.0	15.0	12.0	
			Temperature (°C)	20.5	....	....	....	....	
	Crystal Lake	439	Moisture (%)....	14.9	13.7	13.1	12.7	12.4	As above.
			Germination (%).	0	1.0	1.0	1.0	0	
	Crystal Lake	650	Moisture (%)....	23.0	15.0	13.8	13.3	13.4	Top crust of moldy corn.
			Germination (%).	0	18.0	13.0	18.0	14.0	
	Crystal Lake	651	Moisture (%)....	21.7	16.1	13.8	13.3	12.3	As above.
			Germination (%).	4.0	14.0	24.0	22.0	12.0	
			Temperature (°C)	6.0	1.0	....	0.5	0.5	
	Crystal Lake	653	Moisture (%)....	21.9	15.6	12.9	12.8	12.7	As above.
			Germination (%).	0	3.0	9.0	85.0	58.0	
Winnebago	Woden......	261	Moisture (%)....	17.0	....	....	....	....	Corn damp, no mold development.
			Germination (%).	6.0	....	....	....	....	
	Woden......	425	Moisture (%)....	21.0	14.9	14.0	13.7	13.3	Top crust of moldy corn.
			Germination (%).	9.0	7.0	4.0	1.0	23.0	
	Thompson...	404	Moisture (%)....	23.0	15.6	13.0	13.1	14.0	As above.
			Germination (%).	1.0	26.0	3.0	22.0	30.0	
			Temperature (°C)	26.0	7.0	....	3.0	1.0	
	Scarville	509	Moisture (%)....	23.1	15.1	13.9	14.0	14.4	As above.
			Germination (%).	1.0	7.0	9.0	9.0	12.0	
			Temperature (°C)	29.5	17.0	....	16.0	13.0	
	Buffalo Center	310	Moisture (%)....	13.5	12.6	12.6	12.7	12.3	Good corn—no mold development.
			Germination (%).	38.0	3.7	18.0	8.0	25.0	

Aspergillus flavus, *A. candidus*, *A. niger*, *A. amstelodami*, *Mucor racemosus* and *Rhizopus arrhizus*. Others of lesser importance were: *Penicillium cyaneum*, *P. westlingi*, *P. verrucosum*, *Citromyces thomi*, *Absidia ramosa*, *A. lichtheimi*, *Aspergillus terreus*, *A. nidulans*, *A. repens*, *A. ruber*, *A. chevalieri*, *Syncephalastrum racemosum*, *Rhinotrichum* sp., *Dematium* sp., *Trichoderma* sp., *Fusidium griseum*, *Fusarium moniliforme*, *Cephalosporium* sp., *Gibberella zeae*, *Diplodia zeae* and *Nigrospora oryzae*.

Corn which had just passed through a winter period of storage in the bins, as that examined in 1942 and 1943, revealed *Penicillium palitans* as the predominating fungus. In many instances this fungus constituted the sole organism in the upper 1-foot zone. Strata of other fungi were also evident, but only because of the favorable conditions of moisture and temperature created by the development of *P. palitans* during the winter period. Thus, *Aspergillus flavus* occasionally was found as a thin greenish-yellow band immediately below the layer of *Penicillium palitans*, and in several instances it was responsible for the molding of wide areas of corn. In these instances higher temperatures were noted in the adjacent areas, reflecting the rapid heat-producing capabilities of this fungus. *Aspergillus candidus* was found occasionally in great abundance at the outer edges or below these warm areas and caused a slight matting of the kernels. Fungi of the *A. glaucus* group frequently were found in the drier corn in close proximity to the mold-matted areas. Blue-eye corn (from which *Penicillium rugulosum*, *P. palitans* and *P. chrysogenum* were isolated) was sometimes found in the outer surface portion of the mold-matted areas, but more frequently in bins not showing matting or other mold development.

Corn which had passed through consecutive winter, spring and summer periods of bin storage, like that examined in 1941, supported many different fungi ramifying throughout its mold-matted region, usually without pronounced stratification. Strata of individual fungi were clearly discernible in a few cases. These fungi included blue-eye corn, *A. flavus*, *Penicillium* spp. and white molds (including *Aspergillus candidus*, *Rhinotrichum* sp. and *Oospora* sp.). Species of *Mucor*, *Rhizopus* and *Absidia* frequently developed throughout the matted corn. Members of the *Aspergillus glaucus* group were the only fungi evident in the drier regions immediately below and at the edges of the mold-matted corn. The remaining fungi listed above were isolated from various regions in the bins during the process of picking off the fungus growths from individual kernels for culture and identification.

PART II—LABORATORY STUDIES

The results of the bin examinations reported in Part I revealed that molds were able to develop on corn under low temperature conditions and that decreases in corn germinability and increases in fat acidity occurred in corn with as little as 12 percent moisture. To supplement these observations, trials were conducted under laboratory-controlled conditions to learn the minimum temperature and relative humidity requirements for the growth of some of these fungi, the minimum relative humidity supporting the molding of corn and the incidence of deterioration of low-moisture corn when stored in tight containers.

MINIMUM TEMPERATURES FOR DEVELOPMENT OF THE FUNGI

The low temperature relationships of the more prevalent fungi occurring in the bins were determined under agar-plate conditions. The blue-eye producing fungi, *Penicillium chrysogenum, P. palitans* and *P. rugulosum,* developed at the minimum tested temperature of 0.5° C., while *Aspergillus flavus, A. candidus, A. niger, A. amstelodami* and *Mucor racemosus* failed to develop after 3 months at 9° C. *Penicillium chrysogenum* grew into large colonies after 1 month at 0.5°, while *P. palitans* and *P. rugulosum* had just started to develop. At 9° C., *P. palitans* and *P. rugulosum* developed similar colonies, but these were smaller than those of *P. chrysogenum.* After 3 months at 0.5° C., *P. chrysogenum* covered nearly the entire agar surface in the petri dishes while the other two fungi developed only small colonies.

MINIMUM RELATIVE HUMIDITY FOR DEVELOPMENT OF THE FUNGI

The minimum relative humidity limits for spore germination and growth of these same fungi also were determined. The method followed was to plant spore material (obtained from test-tube agar-slant cultures) on a thin film of solidified, moisture-conditioned plain carrot-extract agar medium carried on circular microscope cover-slips, 18 mm. in diameter. This medium was first exposed (in sterile petri dishes) to the drying atmosphere of the laboratory for 1 day after its application to the cover-slips. The cover-slips carrying the spores were then inverted and sealed with vaseline over the open ends of small glass thimbles which were approximately 25 mm. high and 16 mm. in diameter (made from the closed-end portion of test tubes). The thimbles were charged to within 2 mm. of the rim with known concentrations of NaCl or $CaCl_2$ solutions for relative humidities of 97.5 to 70 percent, spaced at 2.5 percent intervals. The following were the minimum relative humidities which supported growth after 3 weeks at 30° C.: *Aspergillus amstelodami* and *A. candidus,* 72.5 percent; *A. niger,* 80.0 percent; *A. flavus,* 82.5 percent; *Penicillium chrysogenum,* 85.0 percent; *P. rugulosum, P. palitans* and *Mucor racemosus,* 87.5 percent. Similar results for some of these fungi have been reported by Galloway (4) and Heintzeler (5).

MOLDING OF CORN AT DIFFERENT RELATIVE HUMIDITIES

The molding of corn at different relative humidities and temperatures was studied in 2-quart fruit jars. The jars were supplied with various concentrations of NaCl and $CaCl_2$ solutions to give a range of humidities from 97.5 to 72.5 percent. The experiment was planned to compare the molding of two popular yellow-dent hybrids artificially infested with spores of eight different fungi isolated from molding corn. The corn was unsterilized. The temperatures 20° C., 25° C. and 35° C. were chosen because they represented the optimum at which certain of the fungi would grow. The two hybrids were Pioneer 307, a hard, flinty-type corn, and Iowa hybrid 3553, a soft, starchy corn. Seed lots of each of those two hybrids containing 13 percent moisture were dusted with spores from one of the eight fungi, while another seed lot of these same hybrids was left uninfested as control. The seed lots were then divided into amounts of 150 gms. and placed in perforated cellophane bags, 1¼ inches in diameter and 6 inches long, open at the top. Three or four of these filled bags were introduced into duplicate jars where they were supported on paraffined ¼-inch wire screens above the salt solutions (fig. 5). The jars of the 25° C. and 35° C. series received four bags of corn consisting of a noninfested control and three bags each infested with the spores of one of three different fungi. The jars for the 20° C. series received only three bags, one of which was a noninfested control; the other two bags contained corn which was infested with the spores of one of two fungi. Of the eight different fungi, three were tested at 35° C., another three at 25° C., while the remaining two were tested at 20° C. All of the jars were closed with Mason lids in a way to

Fig. 5. A series of 2-quart fruit jars charged with fungus spore-infested and noninfested corn contained in perforated cellophane bags. From left to right, 97.5, 92.6, 87.7, 82.5, 77.2 and 72.5 percent relative humidity.

TABLE 4. DAYS TO THE FIRST APPEARANCE AND THE RELATIVE ABUNDANCE OF FUNGUS GROWTH ON INFESTED AND UNINFESTED CORN STORED AT DIFFERENT RELATIVE HUMIDITIES AND TEMPERATURES.

Temperature °C	Fungus infestation	Observation time	Percentage relative humidity 97.5	92.6	87.7	82.5	77.2	72.5
35	*Aspergillus niger*		10*	12	15	25	40	50
		45 days	△△△†	△△△△	△△	△	t‡	0
		9 mos.	△△△△	△△△△△	△△△	△△	△△	△
35	*A. flavus*		12	15	17	26	29	50
		45 days	△△	△△	△	△	△	0
		9 mos.	△△△△△	△△△△	△△△	△△	△	△
35	*Penicillium* sp.		12	16	17	25	34	52
		45 days	△△	△△	△△△	△	t	0
		9 mos.	△△△△	△△△△△	△△△△	△△	△	△
35	None		20	21	23	30	40	55
		45 days	△△△	△△	△	△	△	0
		9 mos.	△△△△△	△△△	△△	△	△	△
25	*Oospora* sp.		15	19	25	30	45	57
		45 days	△△	△	△	△	△	0
		9 mos.	△△△△	△△	△	△	△	△
25	*Aspergillus* sp. (*glaucus*)		13	18	22	33	45	60
		45 days	△	△	△	△	△	0
		9 mos.	△△△	△△	△	△	△	△
25	*A. amstelodami*		14	18	23	32	42	62
		45 days	△	△	△	t	t	0
		9 mos.	△△△	△△	△△	△	△	△
25	None		17	20	25	31	47	67
		45 days	△△	△	△	t	0	0
		9 mos.	△△△△	△△	△	△	△	t
20	*Penicillium chrysogenum*		19	20	23	35	48	58
		45 days	△	△	△	t	0	0
		9 mos.	△△△	△△	△△	△	△	t
20	*Penicillium* sp.		18	19	23	40	50	68
		45 days	△	△	△	t	0	0
		9 mos.	△△	△△	△	△△	△	△
20	None		20	23	30	45	49	72
		45 days	△	△	△	△	0	0
		9 mos.	△△△	△△	△	t	t	t

*Time in days when fungus growth was first visible.
†Relative abundance of fungus growth.
‡Trace—fungus growth barely visible on a few kernels.

permit some air exchange. This was done by turning the lids gently against the rubber rings around the neck of the jars.

The number of days between the start of the experiment and the first appearance of mold growth on Pioneer hybrid 307 is tabulated in table 4 and plotted in fig. 6. Similar results, not presented, were obtained for Iowa hybrid 3553, except that the fungus growth appeared on this corn a day to several days earlier and usually was more luxuriant. As may be seen from fig. 6, mold growth appeared within 10-20 days at 97.5 percent r.h. and within 50-72 days at 72.5 percent r.h. at the three temperatures tried. The number of days which were required for the

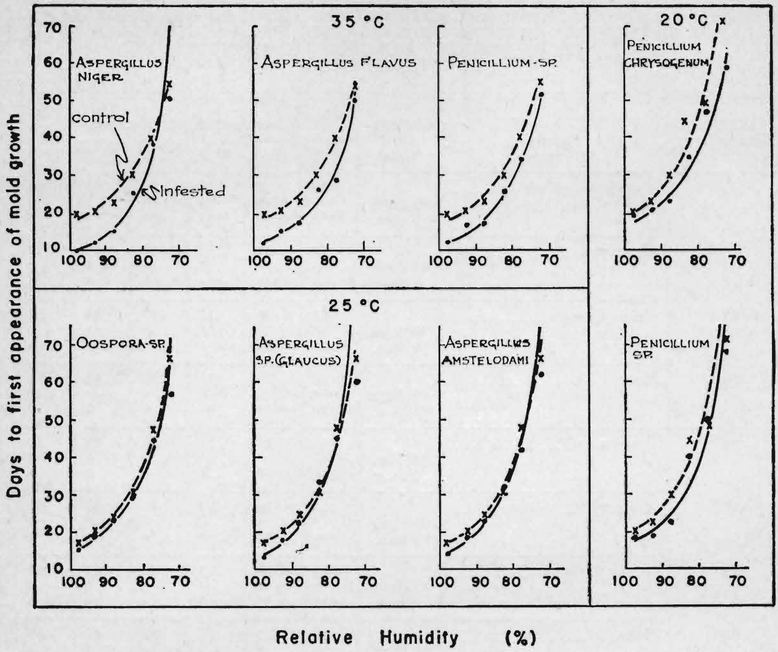

Fig. 6. Days to the first appearance of mold growth on infested and noninfested corn held at different relative humidities and temperatures. As only one noninfested control was used at each of the temperatures, for ease of comparison this control was plotted against each of the fungi tested at the same temperature. The points were the observed values (see table 4), while the curves were drawn from the values of $1/\hat{Y}$ derived from the regression equation and statistics presented in table 5.

first appearance of mold growth at the different relative humidities conformed to a hyperbolic regression (xy = k) at the three temperatures and with the different fungus infestations. In general, the first appearance of mold growth on the infested and noninfested corn was earliest at 35° C., intermediate at 25° C. and latest at 20° C. at all the tested humidities. Mold growth appeared earlier on the infested corn than on the noninfested controls. The coefficients of the linear regressions derived from the reciprocals of the number of days for the first appearance of mold growth (y) on relative humidity (x) are presented in table 5.

Since different fungi were employed at each of the different temperatures, no direct comparison can be made between the fungi used at the different temperatures. Comparison is possible, however, between the different fungi at any one temperature (see table 4). Thus at 35° C., *Aspergillus niger*, a rapid grower, appeared earlier on corn at the higher humidities than either *A. flavus* or *Penicillium* sp. At 77.2 percent r.h. this

TABLE 5. STATISTICS OF THE LINEAR REGRESSIONS* OF THE RECIPROCALS OF THE NUMBER OF DAYS FOR THE FIRST APPEARANCE OF MOLD GROWTH ON PERCENTAGE RELATIVE HUMIDITY.

Temperature	Fungus	$\bar{y}$	b†	value of x when $\hat{Y}=0$
				r. h. ‡
35°C.	*Aspergillus niger*	.056	.0034	68.5
	A. flavus	.050	.0025	65.0
	Penicillium sp.	.049	.0025	65.4
	None—control	.036	.0014	59.3
25°C.	*Oospora* sp.	.039	.0020	65.5
	Aspergillus sp. (glaucus)	.041	.0024	67.9
	A. amstelodami	.040	.0022	66.8
	None—control	.036	.0018	65.0
20°C.	*Penicillium chrysogenum*	.036	.0016	62.5
	Penicillium sp.	.035	.0018	65.6
	None—control	.030	.0015	65.0

*$\hat{Y} = \bar{y} + b\ (x - 85)$.
†P less than 0.001 for all regressions.
‡These values are the asymptotes for the curves shown in fig. 6.

situation was reversed. At 25° C. and 20° C. the differences between the fungi were not so clearly marked, except for 20° C., at which temperature *Penicillium chrysogenum* appeared earlier than *Penicillium* sp. at 82.5 and 72.5 percent r.h.

The hyperbolic nature of the regression of the number of days required for molds to develop on corn held at different relative humidities invites speculation on the minimum relative humidity values that are thresholds for growth of molds. Such values, calculated from the regression equations and shown in table 5, ranged from 59.3 percent r.h. for the control at 35° C. to 68.5 percent r.h. for *Aspergillus niger* infestation at the same temperature. Except for this low value of 59.3 percent r.h., the remaining values were approximately the same at the different temperatures, ranging from 62.5 to 68.5 percent with a mean of 65.7 percent r.h. This mean limit is lower than the 75 percent limit for mold growth on corn as reported by Koehler (7) but agrees with the 65 percent limit for the molding of feeding stuffs reported by Snow et al. (12, 13).

The identity of the molds developing on the corn was determined as far as possible by visual inspection. The fungi whose spores were dusted on the seeds were predominant on the corn under study only in the initial stages of molding. These fungi, however, were soon overgrown by species of *Aspergillus, Penicillium* and of the *Mucoraceae* which are normally carried by the seeds.

The relative development of the molds at the different relative humidities and temperatures, at 45 days and at 9 months after the start of the experiment, shown in table 4, was progressively greater at the higher humidities.

After 9 months of storage there was complete loss of corn germinability at all humidities at 35° C. and at all relative humidities, except 77.2 and 72.5 percent, at 25° C. and 20° C. At 20° C. there was no loss of corn germinability at these low relative humidities. At 25° C. germinability was almost completely lost in the infested corn and partially lost in the non-infested corn.

DETERIORATION OF LOW-MOISTURE CORN STORED IN TIGHT CONTAINERS

The deterioration of low-moisture corn in tightly closed containers was studied in the laboratory over a 2-year period. A quantity of No. 2 yellow corn of the current season with approximately 16 percent moisture was divided into five lots. These were dried over several days to 9.7, 11.0, 12.0, 13.0 and 14.0 percent moistures, respectively. Corn with each of these moisture contents was then placed in six replicated containers.

The containers were constructed of galvanized sheet iron, 8 inches in diameter and 3 feet high, each holding 0.84 bushel of corn. A glass window was provided in the upper half of each container to expose the corn to view. All the joints were watertight and were waterproofed where necessary with caulking compound. After being filled with corn the containers were covered with tightly fitting, circular, galvanized iron disks and sealed with caulking compound. Four circular openings plugged with tightly fitting No. 4 rubber stoppers were provided along the side of each container at distances of 8, 16, 24 and 32 inches from the bottom. These were used to remove samples.

The results after 1 and 2 years of storage at 20-25° C. are shown in table 6. After 1 year of storage, noticeable deterioration occurred only in the 14.0 percent moisture corn. The germinability of this corn had decreased to 54.2 percent from the initial 92.0 percent, the fat acidity had increased to 41.3 units

TABLE 6. DETERIORATION OF LOW-MOISTURE CORN AFTER 1 AND 2 YEARS OF STORAGE IN TIGHT METAL CONTAINERS.

Moisture percentage*			Germination percentage			Fat acidity units			Damage percentage†		
Initial	1 yr.	2 yrs.	Initial	1 yr.	2 yrs.	Initial	1 yr.	2 yrs.	Initial	1 yr.	2 yrs.
9.7	11.4	9.8	92.0	87.5	91.3	24.9	24.7	26.1	3.6	3.7	3.7
11.0	12.0	11.4	92.0	89.9	85.2	24.9	24.9	36.7	3.6	3.7	3.4
12.0	13.3	12.1	92.0	88.3	65.5	24.9	30.2	40.3	3.6	3.2	4.0
13.0	14.1	13.1	92.0	89.9	26.0	24.9	32.4	49.8	3.6	4.3	4.4
14.0	15.2	14.8	92.0	54.2	0	24.9	41.3	68.9	3.6	7.1	45.6

*Moistures determined with a Tag-Heppenstall moisture meter on the initial samples and those after 2 years; the air-oven was used for moisture determinations on samples at 1 year.

†Determined by a federal licensed grain inspector.

from the original 24.9 units, while the percentage of damaged corn had increased to 7.1 percent from the original 3.6 percent. Blue-eye damaged kernels and members of the *Aspergillus glaucus* group developed in this corn. The lower moisture corns showed no change in damaged corn or germinability at this time. There were, however, slight increases in fat acidity in the 12.0 and 13.0 percent moisture corns.

After 2 years of storage, the 14.0 percent moisture corn suffered complete loss of germinability, the percentage of damaged kernels had increased to 45.6 percent, while the fat acidity had increased to 68.9 units. In this time the germinability of the 13 percent moisture corn decreased to 26.0 percent, the fat acidity increased to 49.8 units, while the percentage of damaged kernels remained unchanged. The 12.0 percent moisture corn showed a decrease in germinability to 65.5 percent and an increase in fat acidity to 40.3 units. The 11.0 percent moisture corn underwent a very slight decrease in germinability and a slight increase in fat acidity. The 9.7 percent moisture corn showed little change from the original analyses in any of these characteristics.

The high corn moisture values after 1 year of storage, shown in table 6, require explanation. These moistures were determined by the air-oven method, a procedure yielding higher moisture values than does the Tag-Heppenstall moisture meter. The Tag-Heppenstall meter was used for moisture determinations at the initial period and after 2 years of storage.

DISCUSSION

Fifty to 75 percent of the bins examined in three different years showed mold development in the upper regions of the contained corn. Approximately 10 percent of the corn in these bins was estimated as moldy. Since the examinations were confined to the high-moisture corn areas of Iowa, no estimate is available of the amount of deterioration that may have occurred in the drier corn sections of the state. Some deterioration might have been expected from the losses already noted in corn having 12-13 percent moisture.

The occurrence of molds in the upper central region within the bins raises problems as to the origin of the additional moisture for the development of molds in otherwise fairly dry corn. At the outset there were inequalities in distribution of moisture within the bins (because of filling each bin with different lots of corn having different moisture contents); but it could not be expected that in 50 to 75 percent of the bins the high-moisture corn would be placed in the upper part. The evidence suggests that the initial unequal distribution of moisture becomes rapidly equalized throughout the bins and that sufficiently high moistures for mold growth in the upper regions must develop after the bins are filled. The theory that the high surface moistures resulted from snow blowing into the bins through the top ventilator during the winter months does not account for the absence of mold development in adjacent bins similarly constructed and protected. Furthermore, the center of mold development in the upper layers was only occasionally directly below the ventilator where snow might be expected to accumulate. A more likely source for the high moisture content of the surface corn would be the condensation of water vapors from the atmosphere above and from the corn below (2). Once mold development becomes established in the corn, higher moisture may be expected to develop as a by-product of mold activity.

The appearance of *Penicillium palitans* in the corn as a broad zone of mold growth during the winter period suggests the ability of this fungus to develop at low temperatures. Such a suggestion was borne out by laboratory tests wherein this fungus, together with others isolated from kernels showing blue-eye, was able to develop at 9° and 0.5° C. The observed development of *P. palitans*, a mold producing characteristic blue-eye, outside the confines of the embryo was perhaps conditioned by the prevailing higher moistures.

The minimum corn moisture content for the development of molds is largely unknown and could not be determined in the present bin inspections. Koehler (7) has noted that 14.3 percent moisture corn supported the growth of the most drouth-tolerant *Aspergillus glaucus* group, while 16.7 percent moisture or more was necessary for the development of blue-eye. The laboratory studies reported here have indicated that 14.0 percent moisture would support blue-eye development. This difference in blue-eye development in the two studies may be due in part to the methods of moisture determination. Koehler determined moistures by drying the corn with a fan in a 100° C. oven over a 4-day period; in the present studies the determinations were made using the Tag-Heppenstall meter. This meter (standardized against a water-oven) is known to give moisture readings of from 1 to over 2 percent lower than the two-stage vacuum-oven method (3, 9, 11). The Iowa agents of the Agricultural Adjustment Administration used this meter to determine the moisture content of the corn placed in the bins.

The occurrence of mold growth on corn at 72.5 percent relative humidity with a possible minimum of approximately 65 percent r.h. raises the problem of the equivalent corn moistures to which these relative humidities correspond. According to Bailey's results (1) these relative humidities should correspond to approximately 14.0 and 13.0 percent corn moistures, respectively, but this transposition is beset with many limitations because of inadequate data covering the relationship. The samples of corn and the methods of moisture determinations are important factors to be considered in arriving at this relationship.

The losses of corn germinability and the increases in fat acidity are changes of fundamental importance. Their occurrence in corn bears directly on the commercial value of the crop and on its subsequent storability. Very little is known about the significance of these changes except that Zeleny (14) has recently reported on the greater heating tendencies of corn that has undergone these changes, while Robertson et al. (10) have reported that older grains lose their vitality more rapidly than the newer grains.

The development of these changes in corn at low moistures of approximately 11 percent introduces problems of maximum moisture limits for the safe storage of corn. The limit of 13.5 percent moisture (as determined by the Tag-Heppenstall meter) is obviously on the border line of safe shelled corn storage. Robertson et al. (10) have noted germinability losses in 11 percent moisture wheat, oats and barley after 1 year storage at 57.6 percent r.h. Greater and more rapid germinability losses occurred under higher moisture conditions, and some losses resulted in wheat on long storage at lower moisture conditions. Jones, Denine and Gersdorff (6) have recently noted that proteins in 10.59 percent moisture corn after 12 months of storage break down into smaller units and become less soluble in various dispersing agents and less digestible by pepsin and trypsin.

The absence or nearly complete absence of insects in the corn examined in the present bin inspections was surprising because of their reported great prevalence in other more southerly sections of Iowa. The few insects observed in the early spring bin inspections were confined to the regions of developing molds where warmer temperatures prevailed. During the late-August early-September inspection of 1941, insects were found in only moderate numbers in 3 out of 58 bins.

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